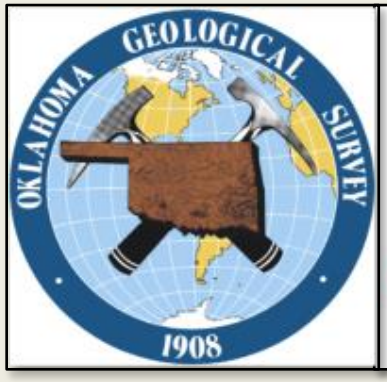


Kyle E. Murray, PhD, Hydrogeologist

Presents:

An Ounce of Understanding is Worth a Pound of Cure

Kansas Induced Seismicity State Task Force Meeting
Newman University

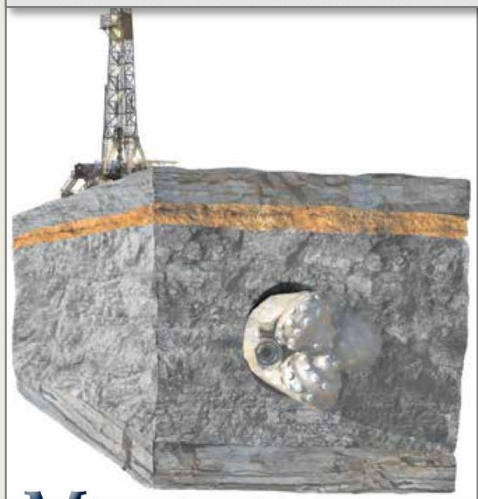
Wichita, KS
April 16, 2014

Speaking to Industry about Water Use and Water Production

Oklahoma Water Survey Workshop – October 25, 2012 – Presentations

[Outreach]

Analysis and Discussion of Oklahoma's Oil and Gas Operations and the Protection of Water Resources



Mississippian and Arbuckle Workshop

October 31, 2012

Oklahoma Geological Survey

G. Randy Keller, Director

The University of Oklahoma

MEWBOURNE COLLEGE OF EARTH & ENERGY

MISSISSIPPI LIME CONGRESS 2012

Mississippi Lime Play: Assessing How Horizontal Drilling And Completions Techniques Can Be Applied Economically To The Geologically Variable Mississippi Lime Formation

November 28-29, 2012 Oklahoma City, USA

MISSISSIPPI LIME PRODUCTION & PRODUCED WATER 2013

Produced Water & Production: Driving Down The Costs Of Recovery In The Mississippi Lime

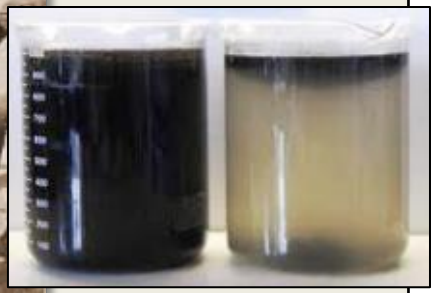
June 26-27 2013, Oklahoma City

MISSISSIPPI LIME & CHERT DRILLING & COMPLETIONS CONGRESS 2013

Optimizing Completions Design And Drilling Techniques To Develop Economic Wells In The High Chert Mississippi Lime Play

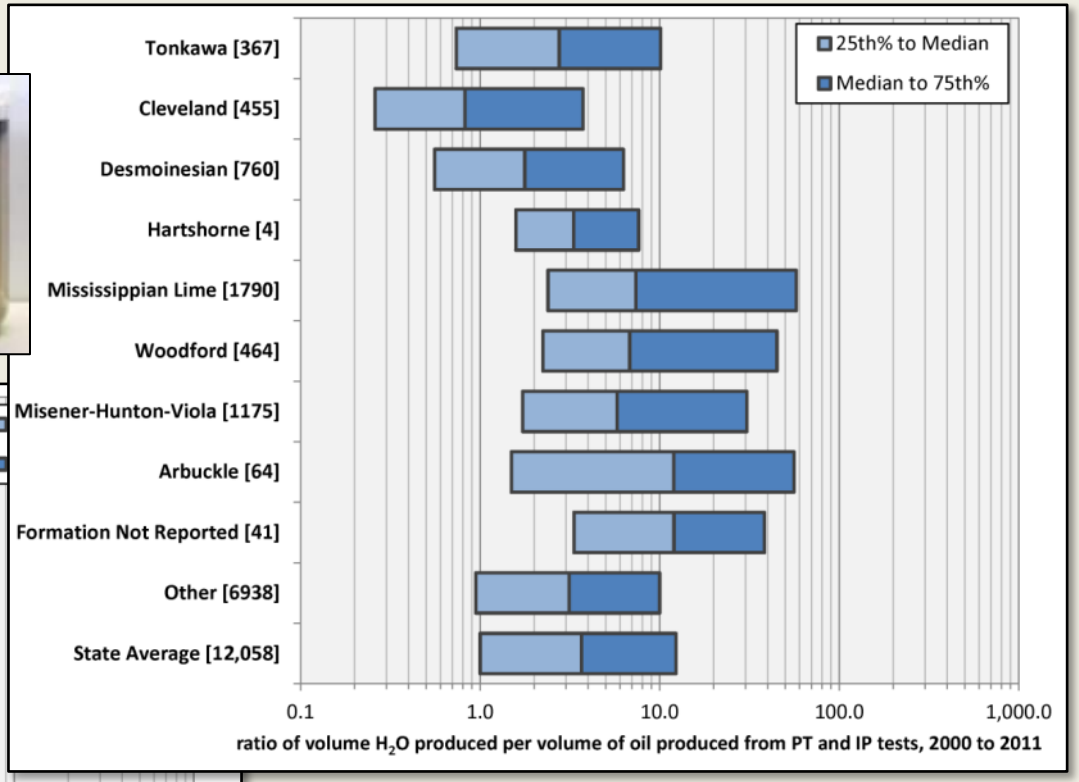
October 29-30, 2013 Oklahoma City, OK

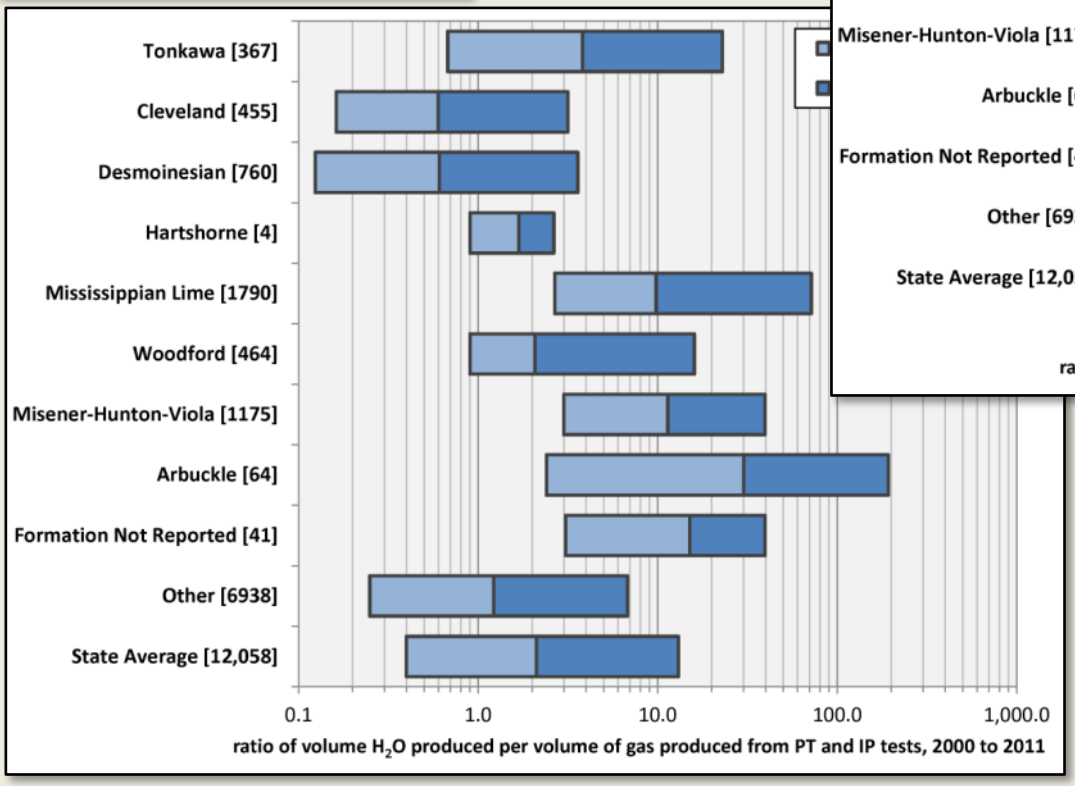
Co-Production of Brine?



From 2000-2011, newly completed wells in OK's Miss averaged:

- **7.4 bbl of H_2O per 1 bbl of oil**
- **9.8 bbl of H_2O per 1 bbl oil equivalent gas**





Murray, K.E., 2013, State-Scale Perspective on Water Use and Production Associated with Oil and Gas Operations, Oklahoma, U.S.: Environmental Science & Technology, v. 47, no. 9, p. 4918-4925.

Examining Water Use, Production and UIC Injection

ENVIRONMENTAL Science & Technology

2013, vol. 47, no. 9, p. 4918-4925

Article

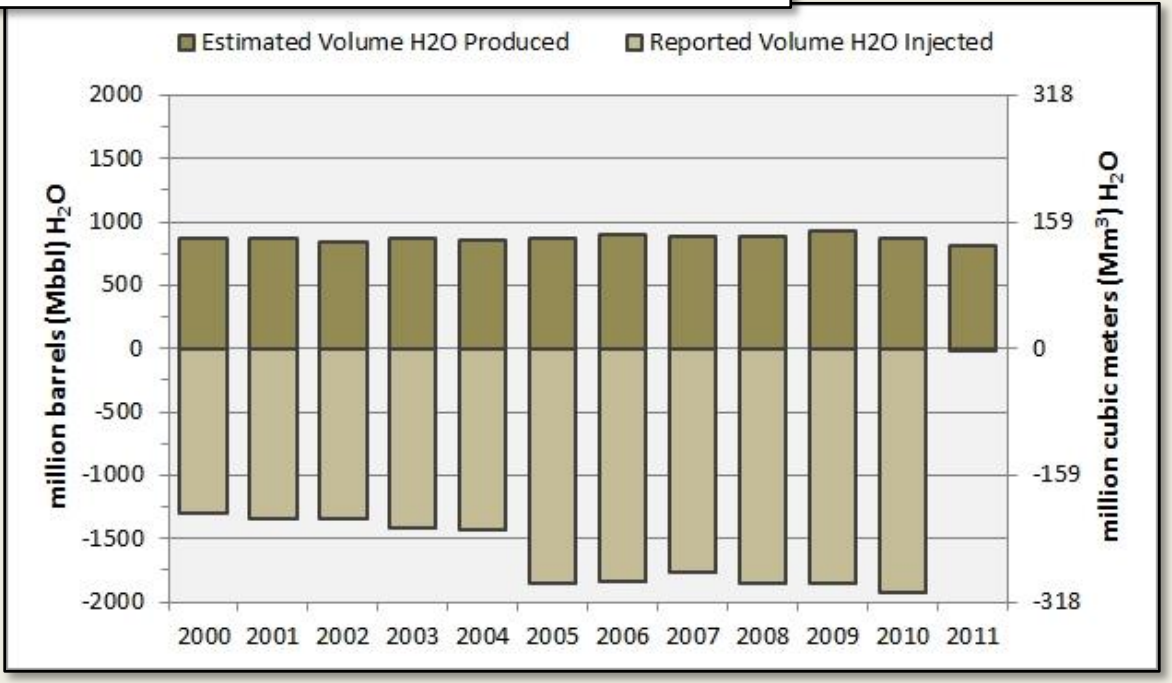
pubs.acs.org/est

State-Scale Perspective on Water Use and Production Associated with Oil and Gas Operations, Oklahoma, U.S.

Kyle E. Murray*

Oklahoma Geological Survey, The University of Oklahoma, 100 East Boyd Street Norman, Oklahoma 73019-0628, United States

Supporting Information, C

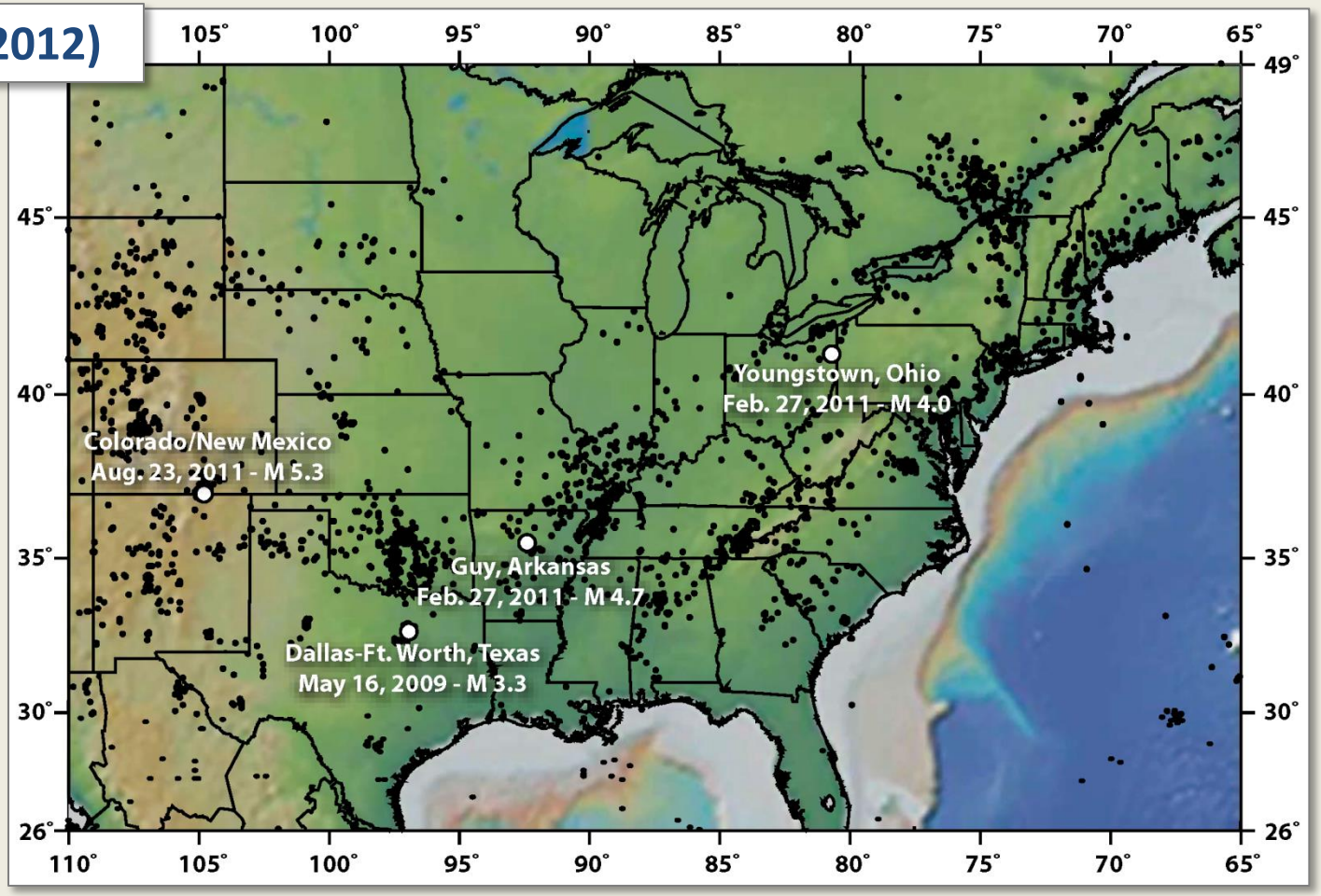


*partially validated w/ online 1012As

Oil Prod 2011 (MMBO)	Gas Prod 2011 (MMBOE)	SW Prod 2011 (MMbbl)	HF Inj 2011 (MMbbl)	SWD Inj 2011 (MMbbl*)	EOR Inj 2011 (MMbbl*)
77	334	808	78	925	641

Seismicity Potentially Induced by Fluid Injection

Zoback (2012)



Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 M_w 5.7 earthquake sequence

Katie M. Keranen[1], Heather M. Savage[2], Geoffrey A. Abers[2], and Elizabeth S. Cochran[3]

[1]ConocoPhillips School of Geology and Geophysics, University of Oklahoma, 100 E. Boyd Street, Norman, Oklahoma 73069, USA

[2]Lamont-Doherty Earth Observatory of Columbia University, PO Box 1000, 61 Route 9W, Palisades, New York 10964, USA

[3]U.S. Geological Survey, 525 S. Wilson Avenue, Pasadena, California 91106, USA

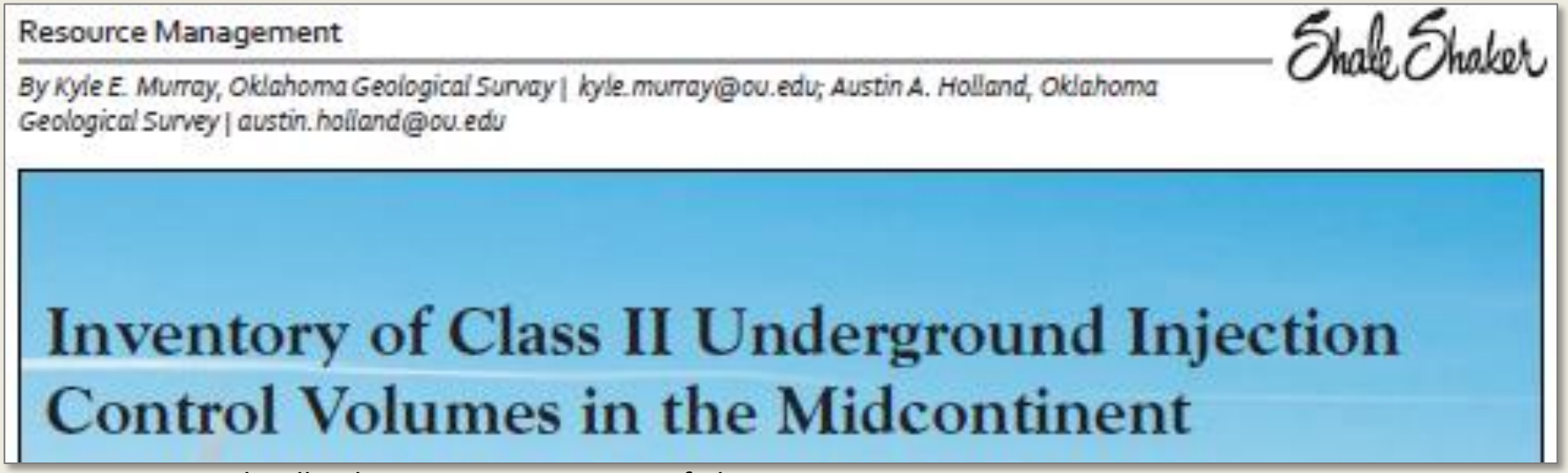
Papers on the Topic

AAPG Extended Abstract for 2014 Annual Convention & Exhibition, Houston, TX
Abstract #

1840901 Subsurface Fluid Injection in Oil and Gas Reservoirs and Wastewater Disposal Zones of the Midcontinent

Kyle E. Murray*, Austin A. Holland; Oklahoma Geological Survey, The University of Oklahoma

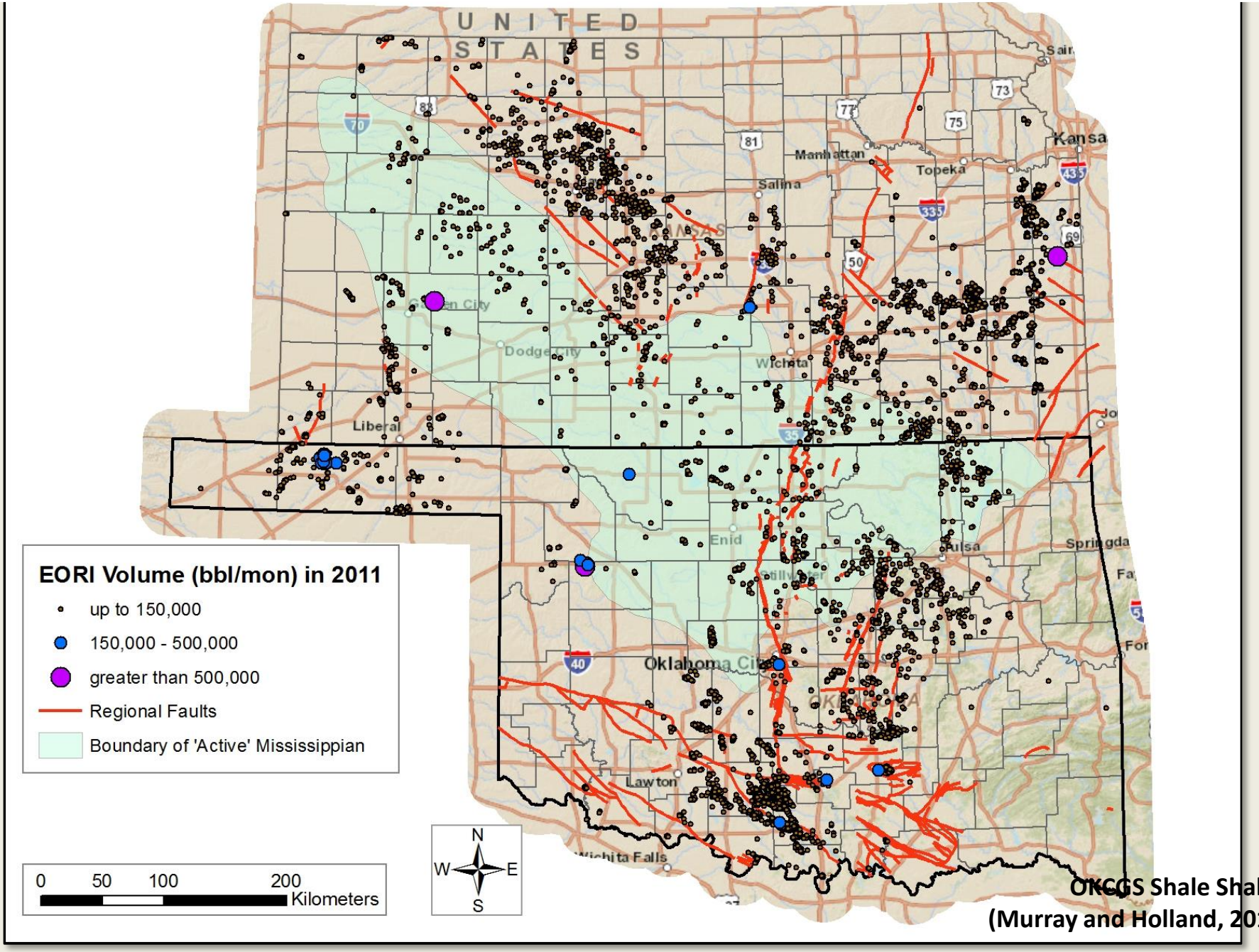
ABSTRACT



Murray, K.E., and Holland, A.A., 2014, Inventory of Class II Underground Injection Control Volumes in the Midcontinent: Shale Shaker, v. 65, no. 2, p. 98-106.

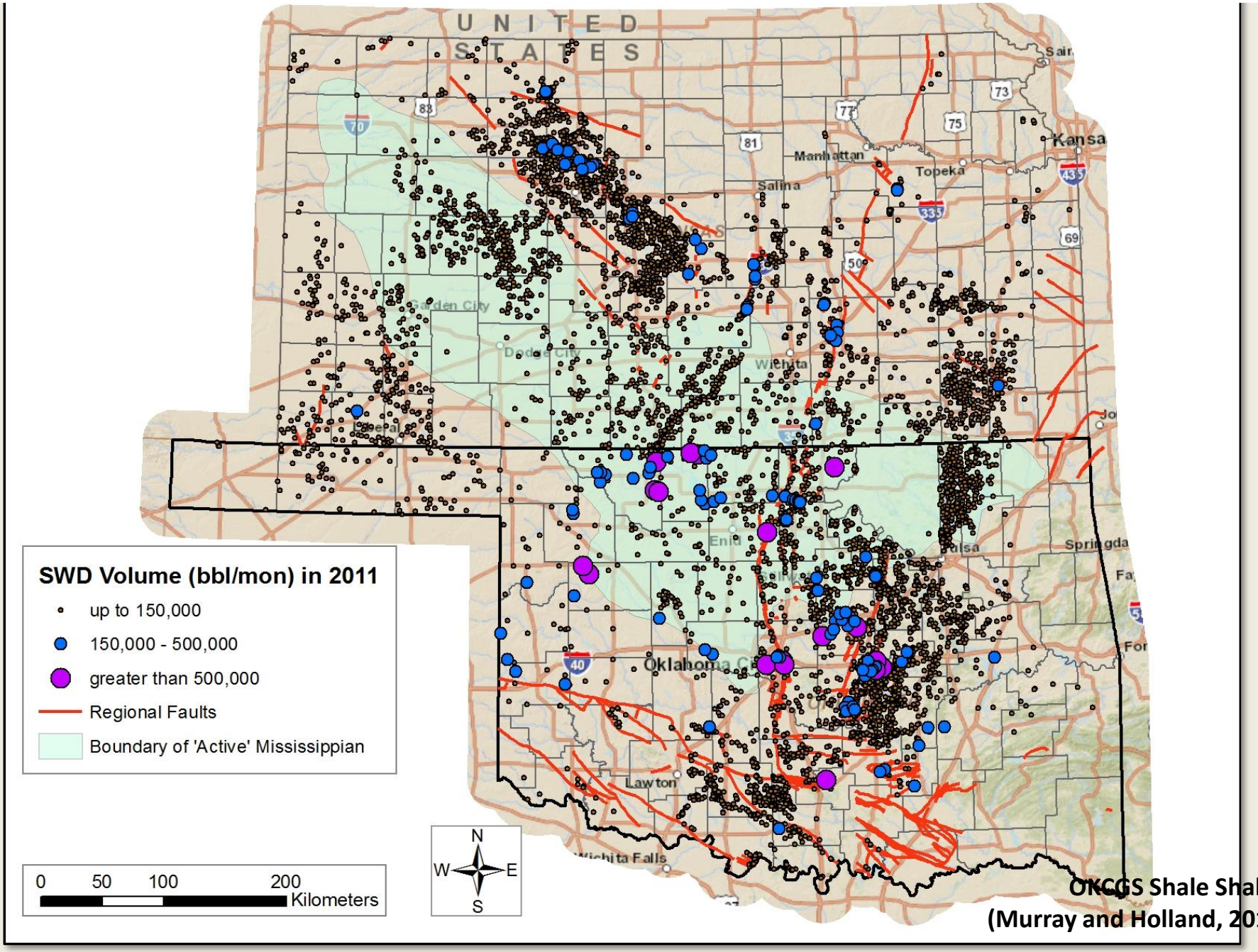
and To Be Continued…

EOR Injection (EORI) Volume (bbl/mon) per Well



OKCGS Shale Shaker
(Murray and Holland, 2014)

SWD Volume (bbl/mon) per Well

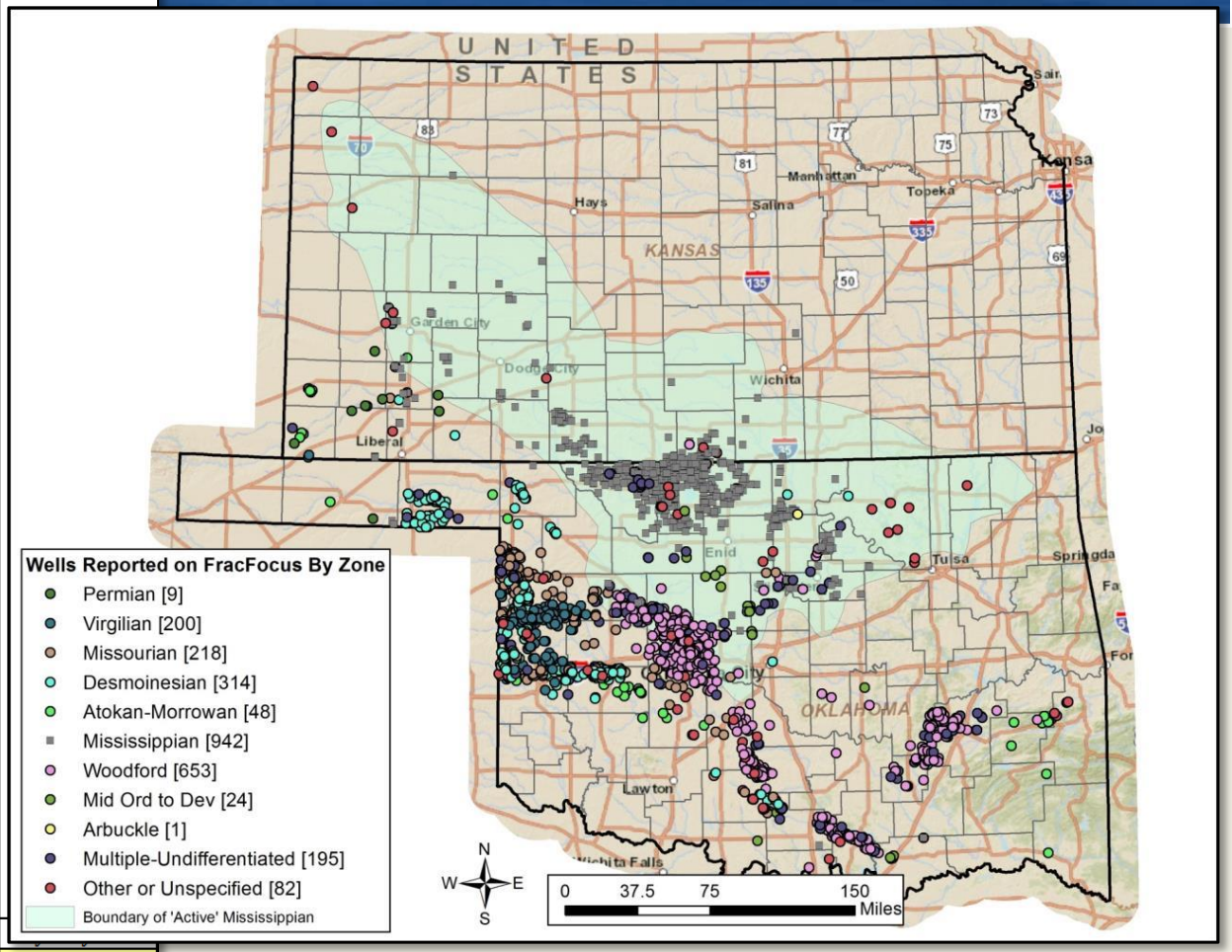


OKCGS Shale Shaker
(Murray and Holland, 2014)

Zones of Production & Class II UIC Wells

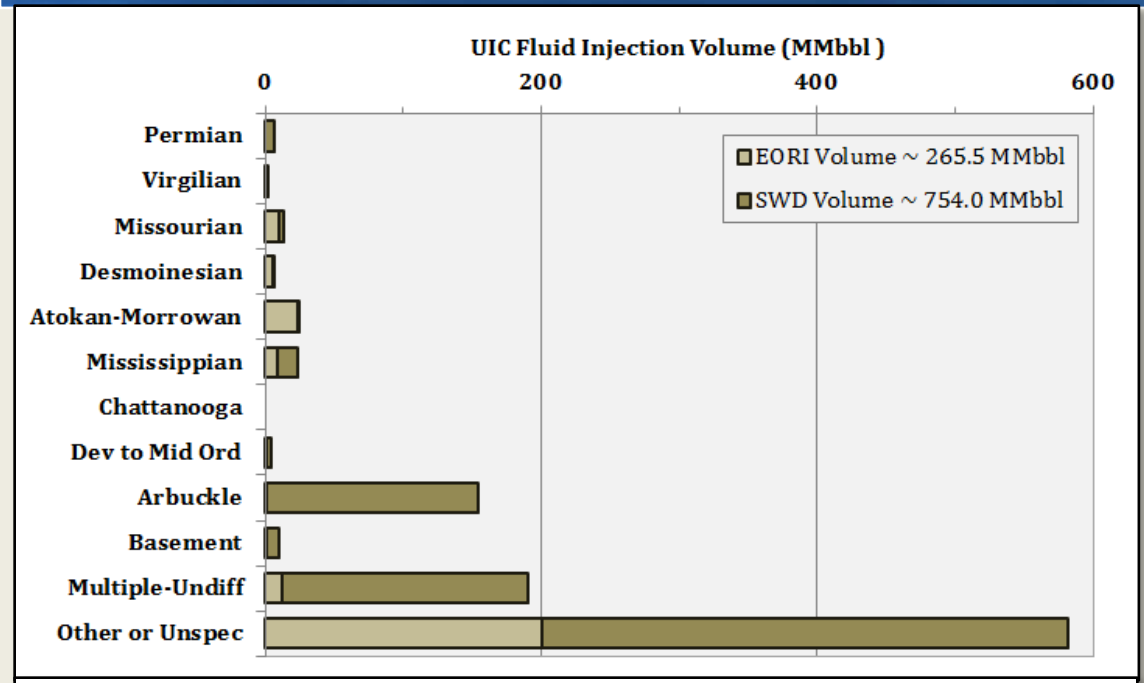
Zone	Group	Formation	
Permian		Garber	
	Chase	Brown Dolomite	
	Council Grove	Pontotoc	
	Admire	Belveal	
Virgilian	Wabaunsee	Cisco Lime	
	Shawnee	Pawhuska	
		Endicott	
	Douglas	Tonkawa	
Missourian	Hoxbar	Lansing	
		Cottage Grove	
		Kansas City	
		Hogshooter	
		Layton	
		Cleveland	
Desmoinesian	Marmaton	Oswego	
	Cabaniss	Skinner	
	Krebs	Red Fork	
		Burbank	
		Bartlesville	
		Hartshorne	
Atokan-Morrowan	Atoka	Gilcrease	
		Dutcher	
	Morrow	Cromwell	
	Springer	Wamsley	
Mississippian	Chester	Manning	
		Caney	
	Meramec	Miss Lime	
		Miss Chat	
		St. Louis	
		Mayes	
	Osage	Sycamore	
	Kinderhook	Kinderhook	
Woodford	Upper Devonian	Woodford	
Dev to Mid Ord	Middle Devonian	Misener	
	Lower Dev - Silurian	Hunton	
	Cincinnatian	Sylvan	
		Viola	
	Simpson	Bromide	
		Wilcox	
		McLish	
		Oil Creek	
Arbuckle	Arbuckle Group	West Spring Creek	
		Kindblade	
		Butterly Dolomite	
Basement & Crystalline Rock	Cambrian	Reagan	
	Pre-Cambrian	Granite	

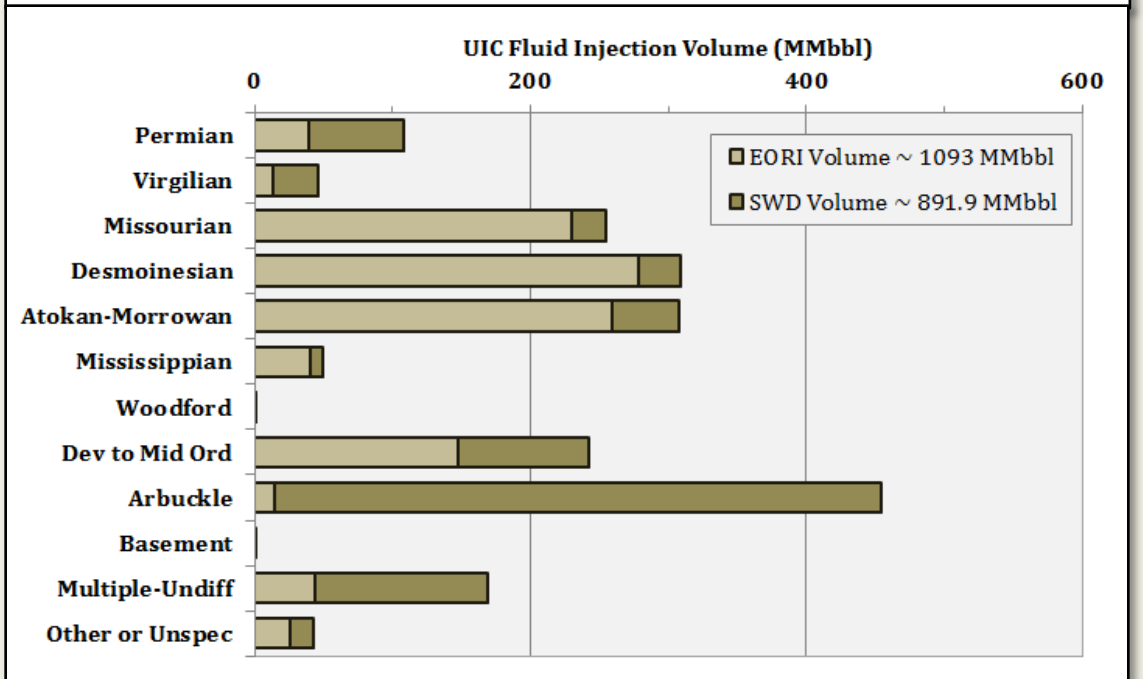
Sandstone	
Carbonate	
Shale	
Coal	
Granite	

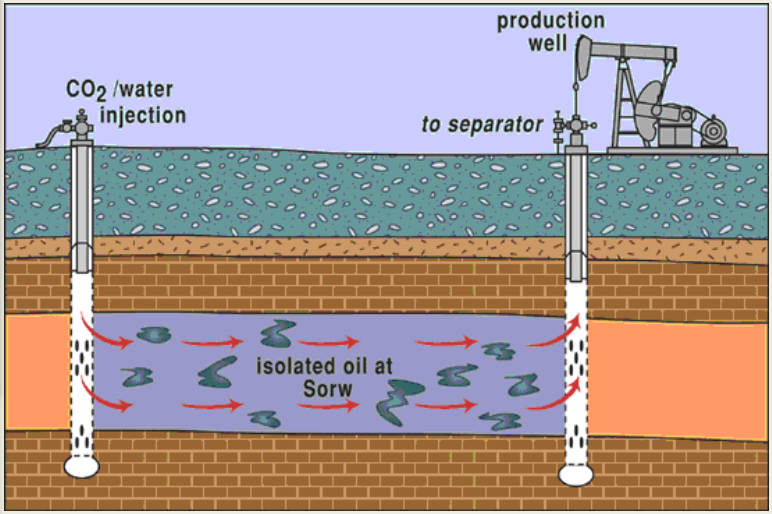


OKCGS Shale Shaker
(Murray and Holland, 2014)

Which zones are used for EORI and SWD injection?



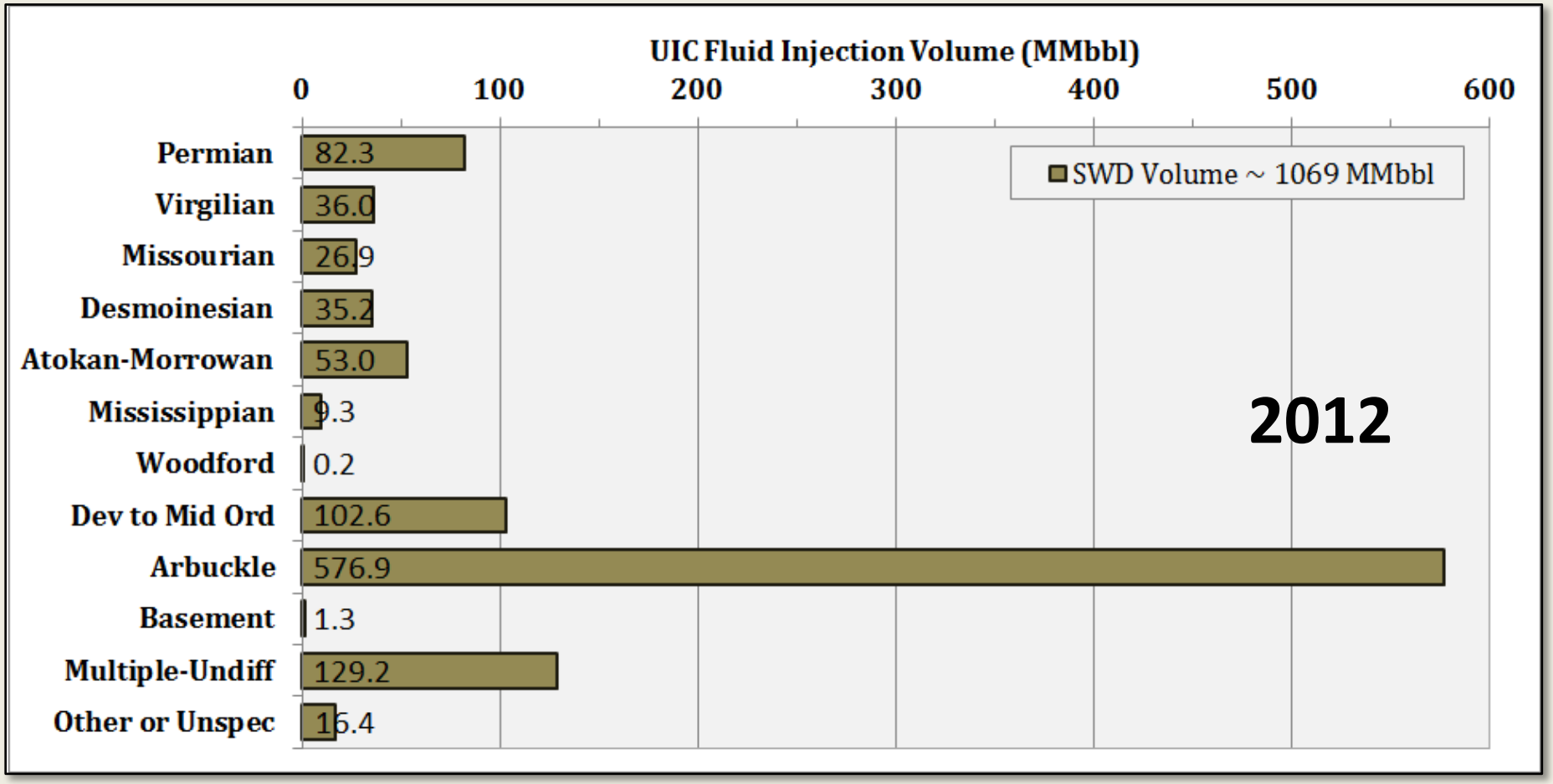




KS UIC data from KGS (2013) Well Database
OK UIC data from Lord (2012) UIC Database

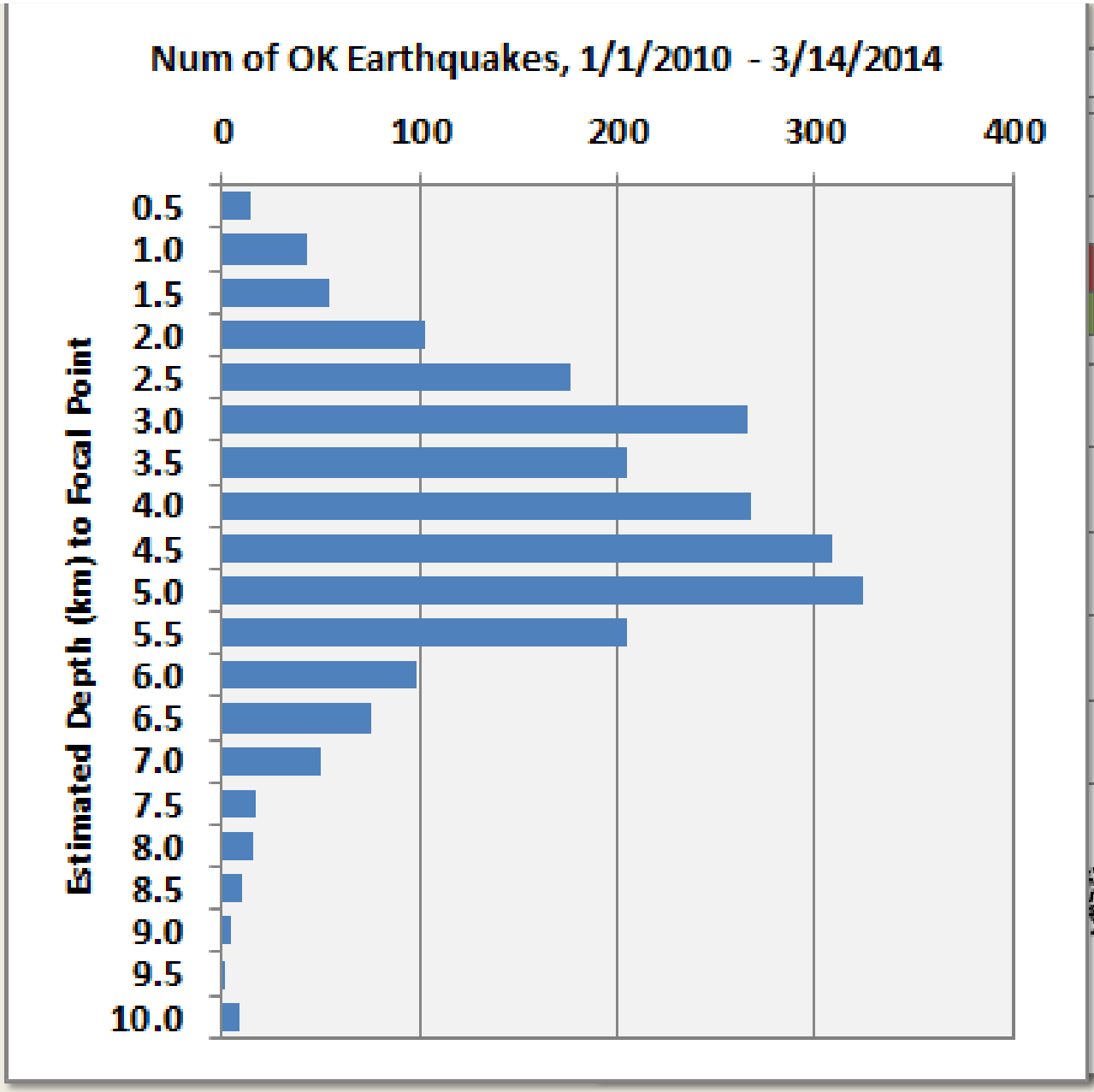
OKCGS Shale Shaker
(Murray and Holland, 2014)

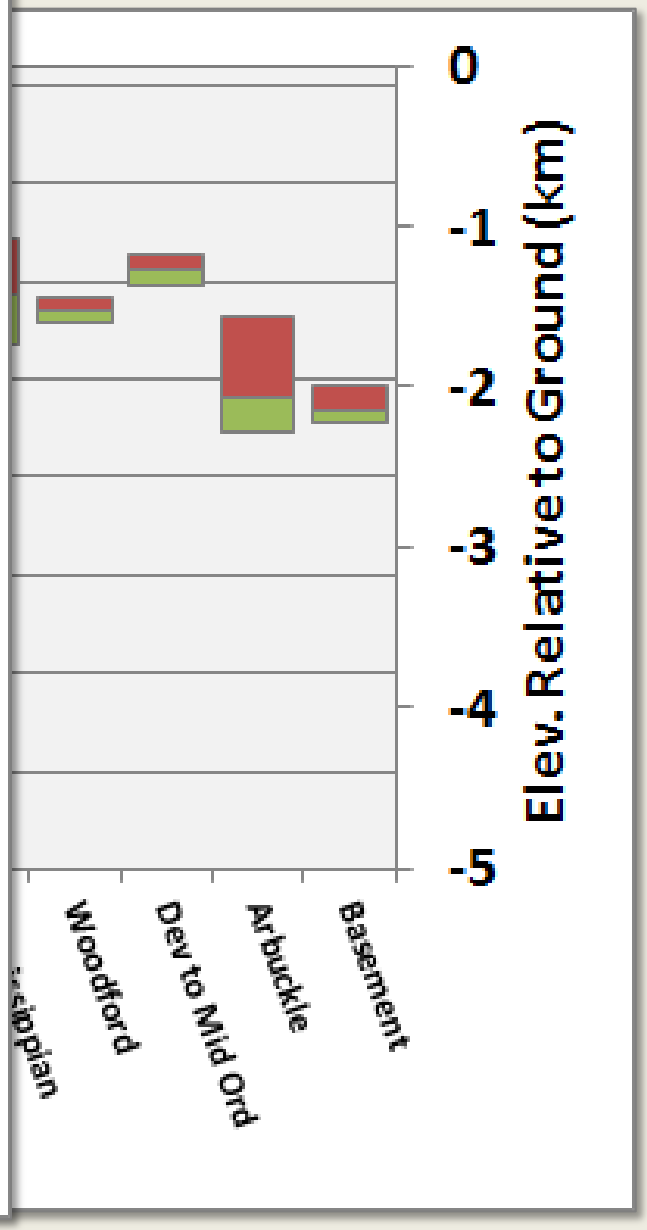
Non-Osage Saltwater Disposal (SWD) Volumes in 2012



Murray, *in preparation*

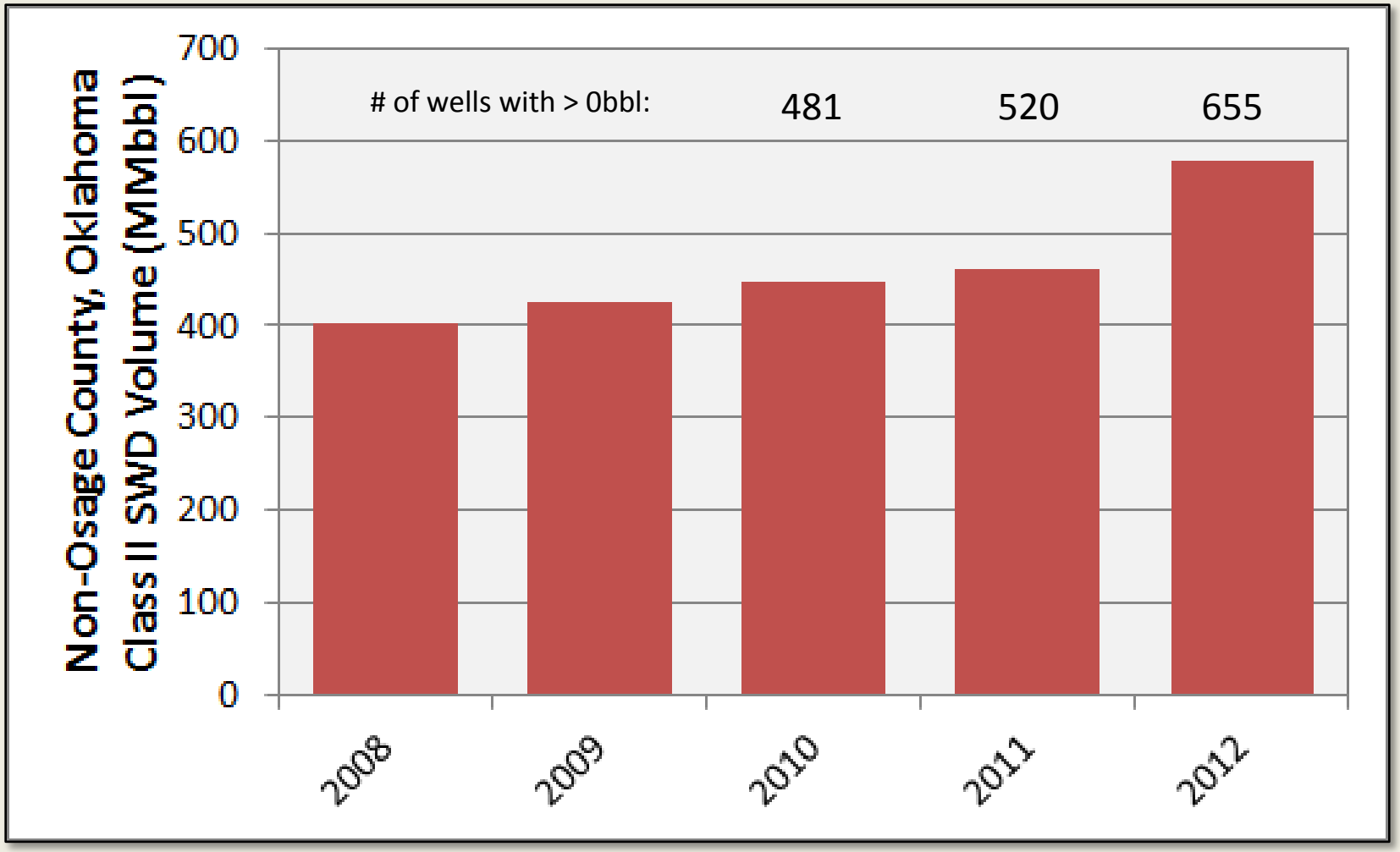
Depths of SWD versus Depths of Earthquakes





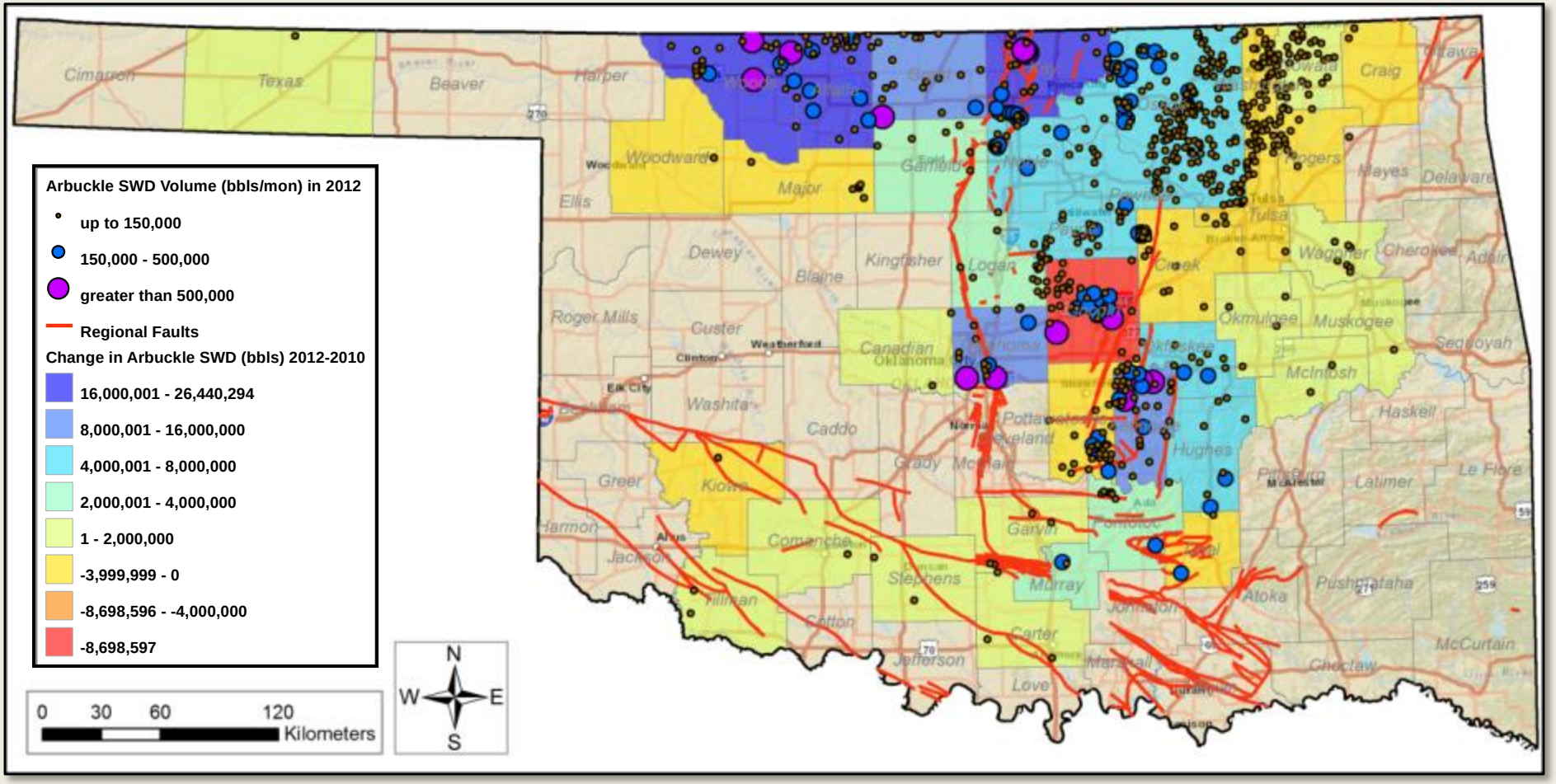
(Holland and Murray, 2014 - *in preparation*)

SWD into Arbuckle Group or Basement versus Time



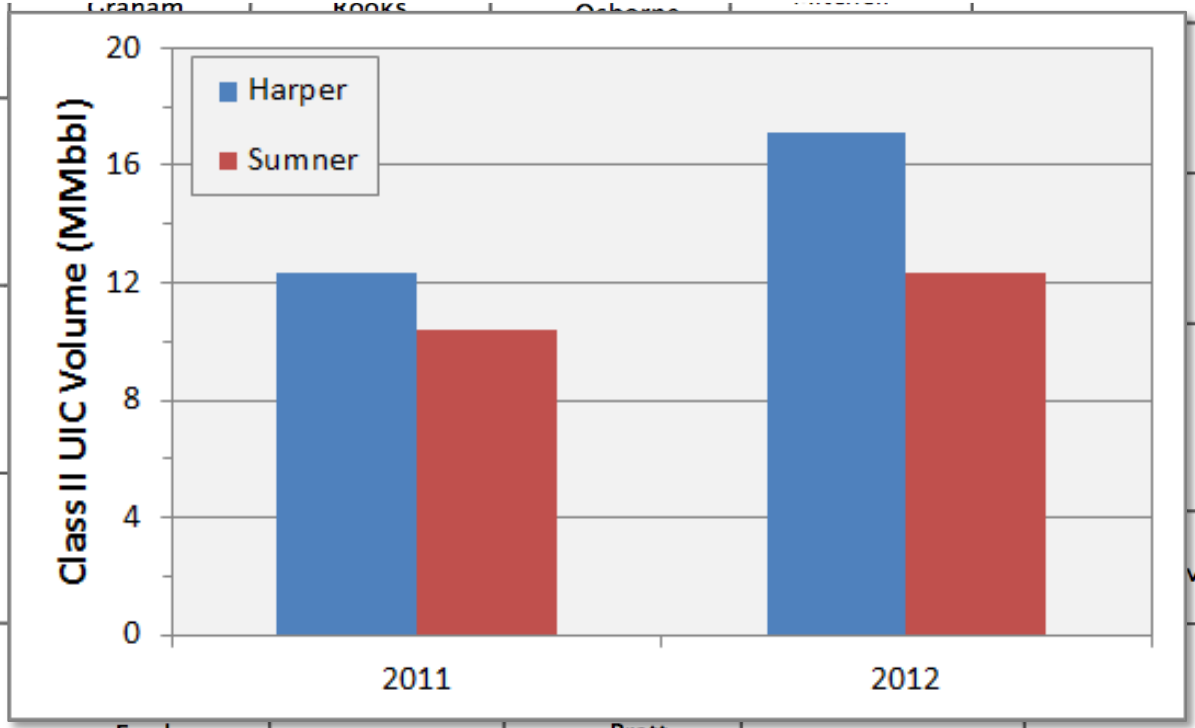
Murray, *in preparation*

Change in SWD into Arbuckle Group or Basement by County



Murray, *in preparation*

KS Earthquakes and UIC volumes in Harper and Sumner



Riley
Pottawatomie
KSU1
Geary
Wabaunsee
Dickinson
Morris
Lyon
Marion
Chase
Greenwood
Butler
Sedgwick
Ford
Kiowa
Pratt
Kingman
Elk
Clark
Comanche
Barber
Harper
Sumner
Cowley
Chautauqua
T35B
KAY1
KAY
PCO
HARPER
WOODS
ALFALFA
GRANT
WASHINGTON
WOODWARD
CROK
OSAGE
U32A
MAJOR
GARFIELD
NOBLE

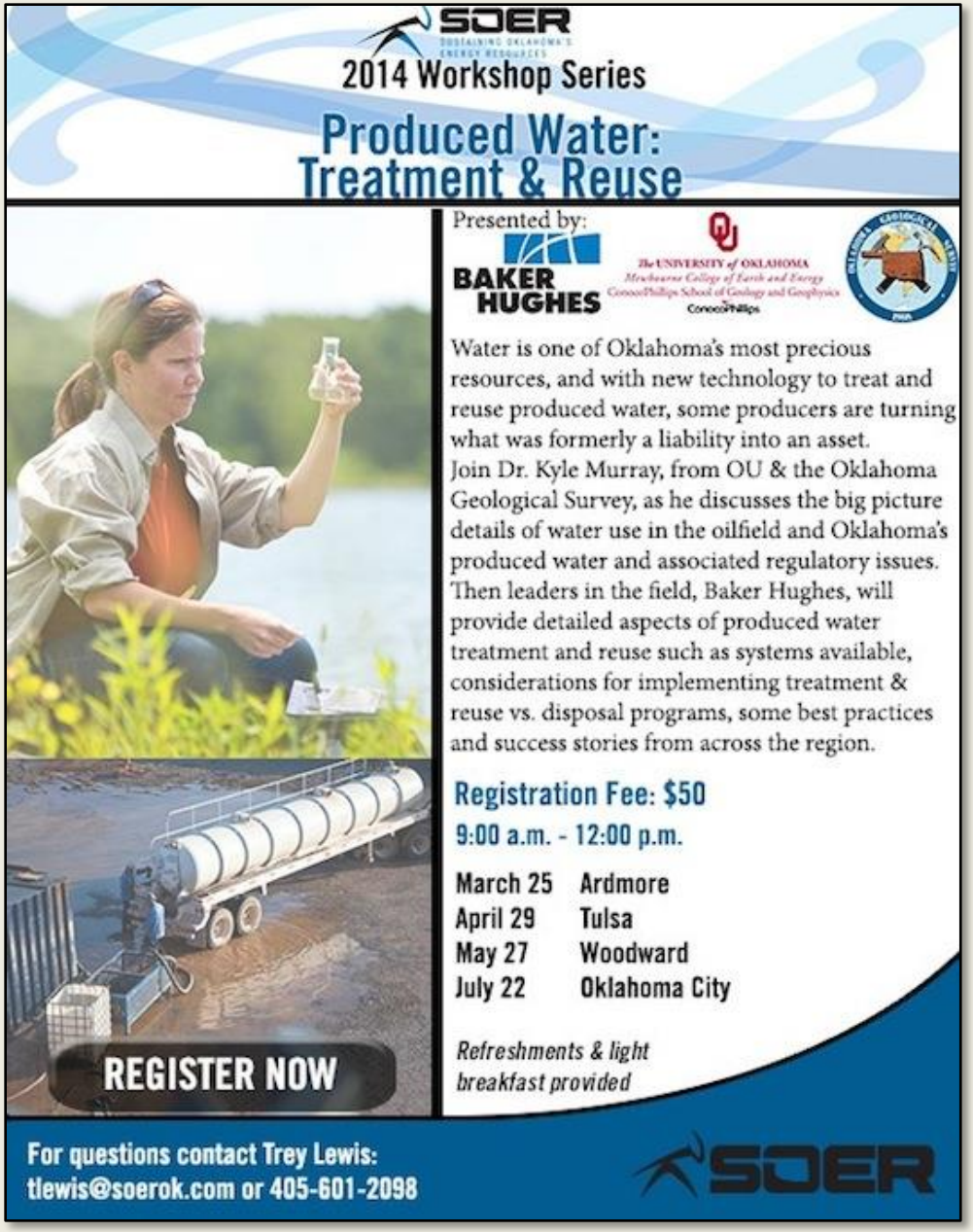
Map of KS Earthquakes from Holland, 2014
KS UIC data from KGS (2013) Well Database

Opportunity Cost?

When a choice needs to be made between mutually exclusive alternatives, **the opportunity cost** is the **value** of the **"best alternative"** forgone.

- loss of potential gain from other alternatives when one alternative is chosen
- opportunity cost plays a crucial part in ensuring that scarce resources are used efficiently

Promoting Recycle and Reuse as an Alternative to SWD



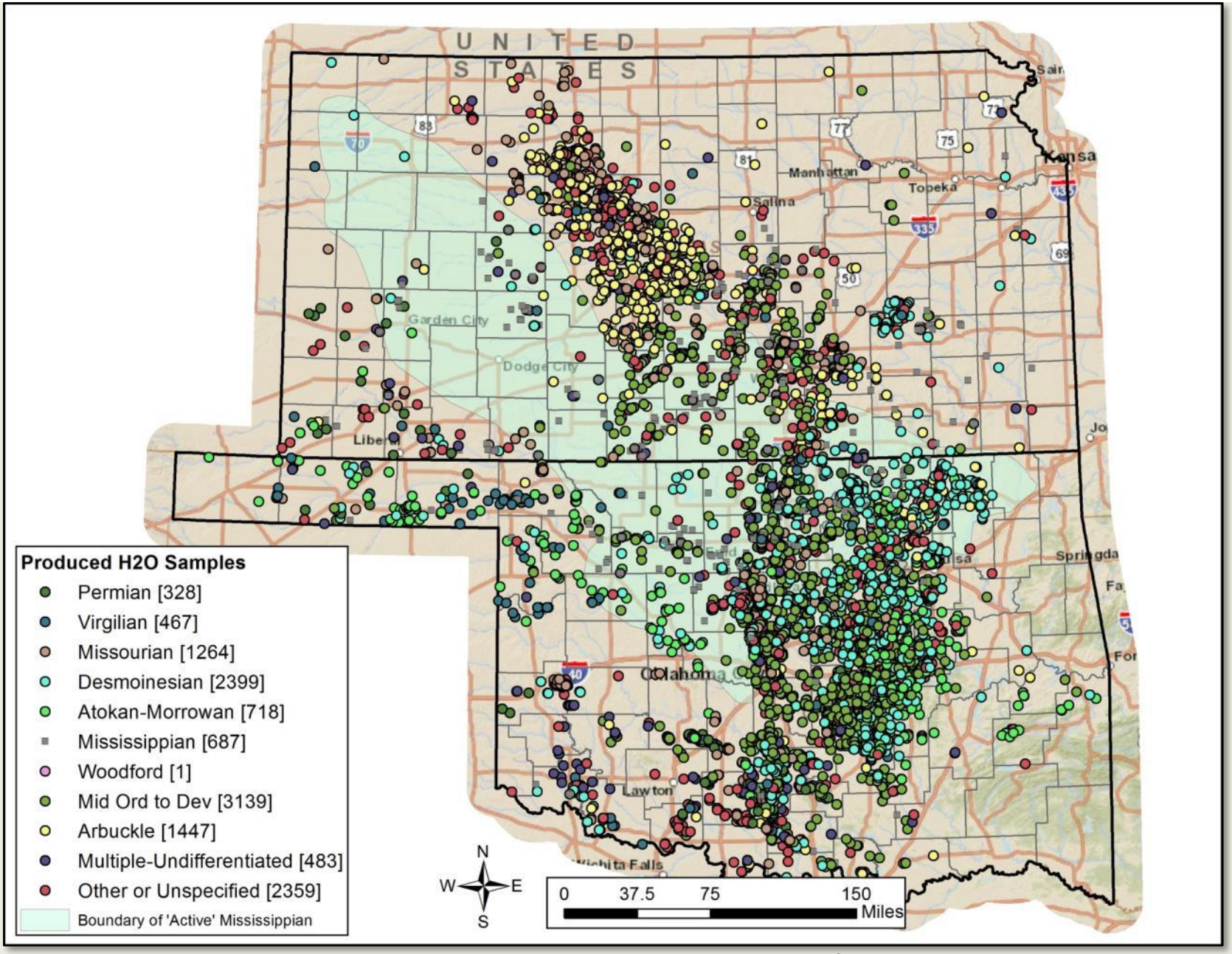
Water Supply Issues

- Cyclic droughts strike state
- Aquifers are in decline due to overuse

Regulatory and Economic Drivers

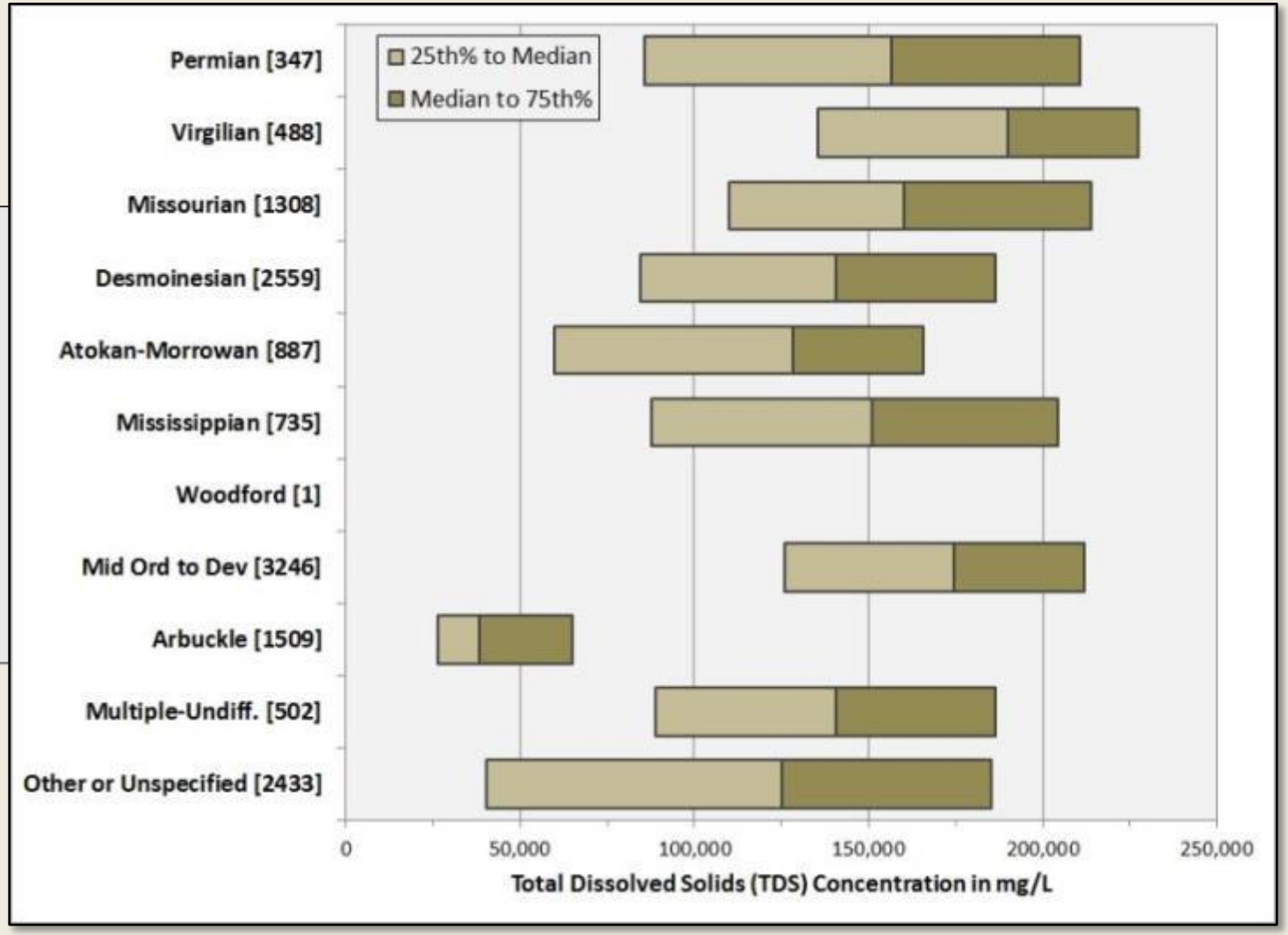
- OK current cost for commercial SWD $0.45 - $2.10 per bbl
- AR had a moratorium on SWD due to induced seismic risk

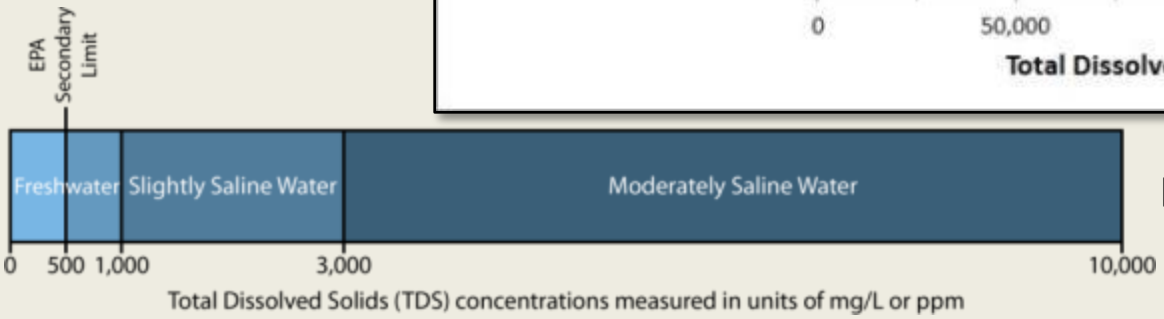
Produced Water Quality in OK and KS



(Murray and Irwinsky, 2014-in preparation)

Concentration of Total Dissolved Solids (TDS) expected in H_2O Produced from Oil & Gas Wells?



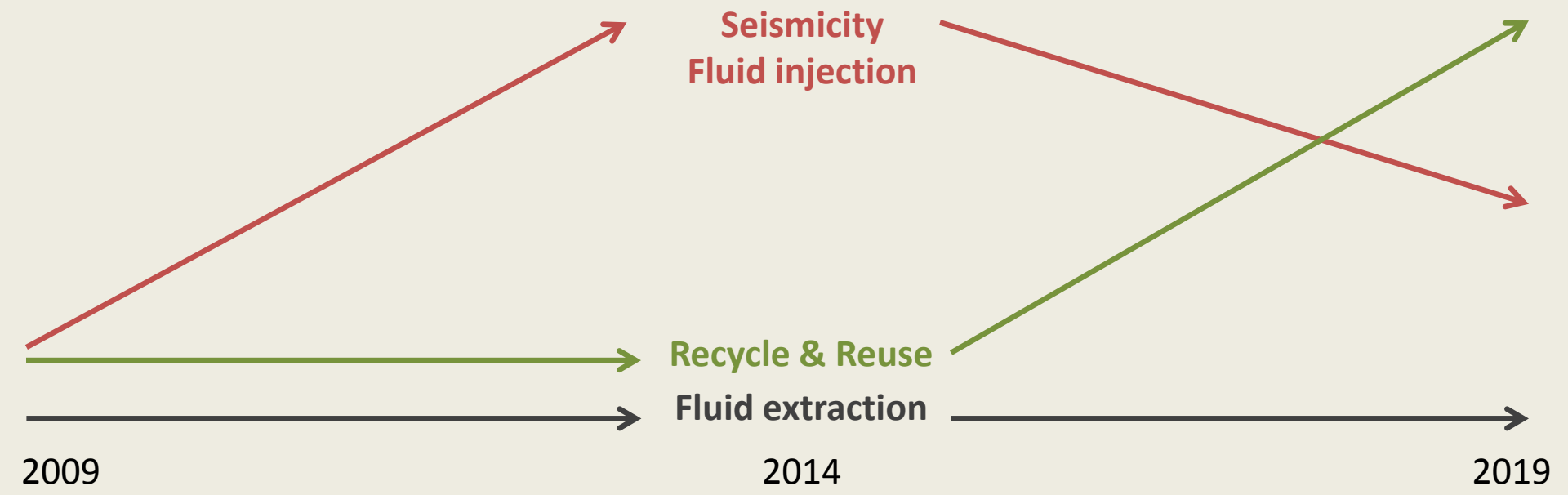


BRINE

(Murray and Irwinsky, 2014-in preparation)

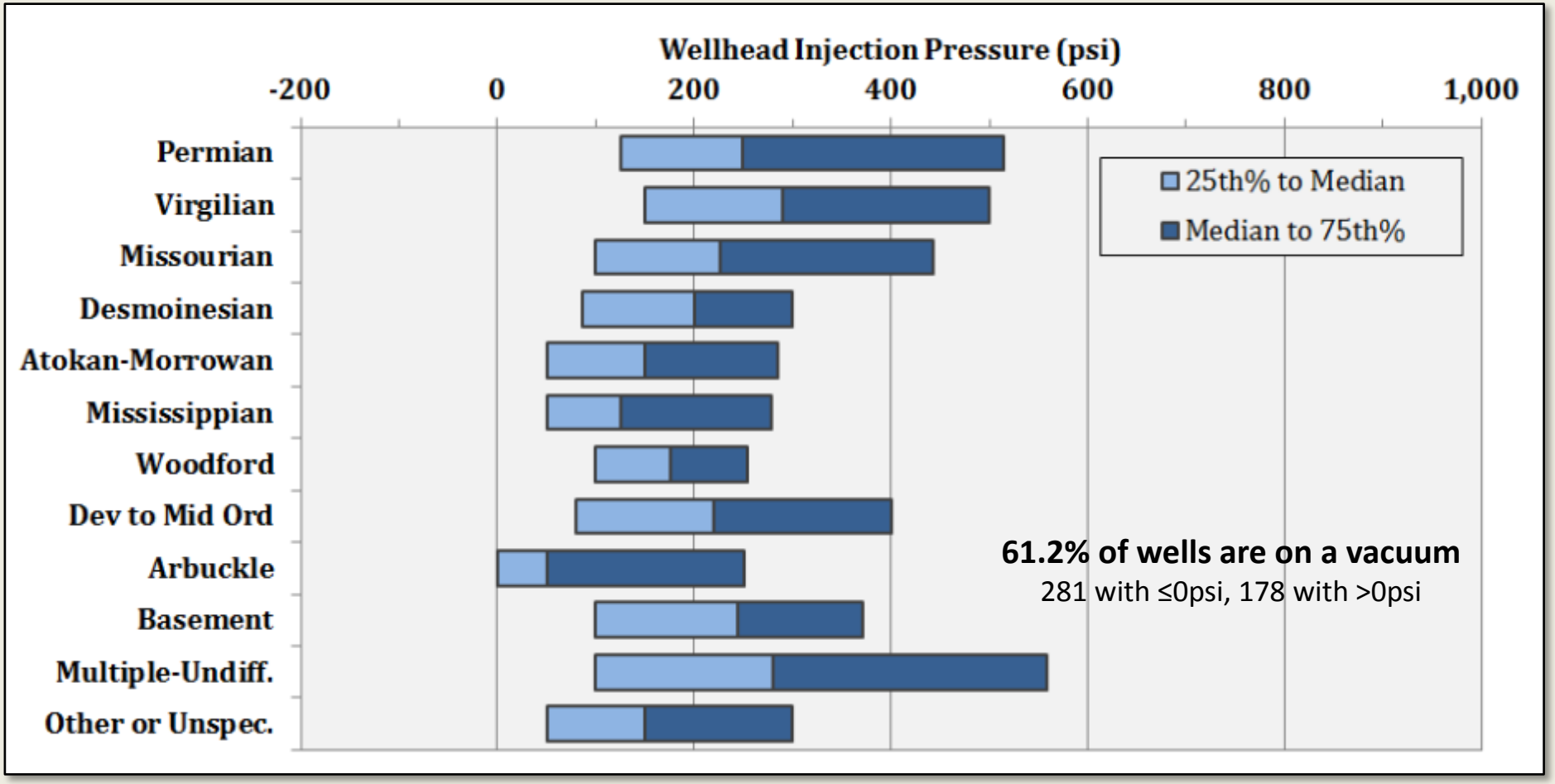
Summary, Forecasting, and Desired Future Conditions

Oil Prod 2012 (Mgal)	Gas Prod 2012 (MgalOE)	SW Prod 2011 (Mgal)	GW Prod 2005 (Mgal)	GW Rech 0.5% prec, 0.17in (Mgal)	HF Inj 2011 (Mgal)	SWD Inj 2012 (Mgal)	EOR Inj 2012 (Mgal)
3,751	14,999	33,946	208,006	206,243	3,276	50,172	63,828



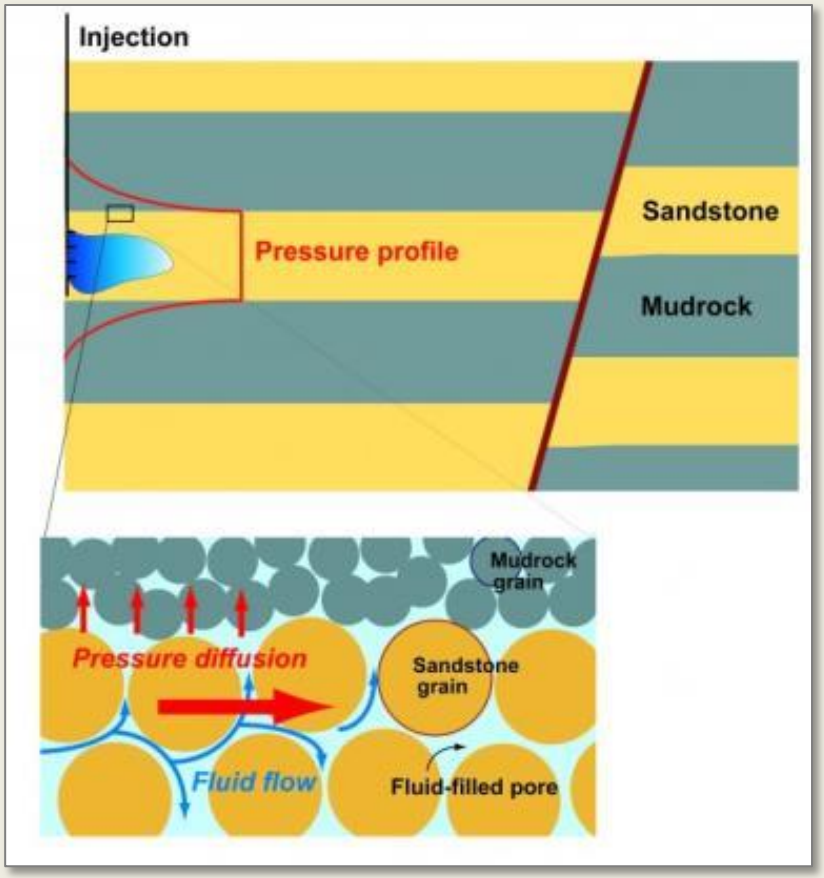
Contact Information
Email: Kyle.Murray@ou.edu
Website: http://faculty-staff.ou.edu/M/Kyle.E.Murray-1/
Phone: (405) 325-7502

Average Annual SWD Injection Pressure by Zone

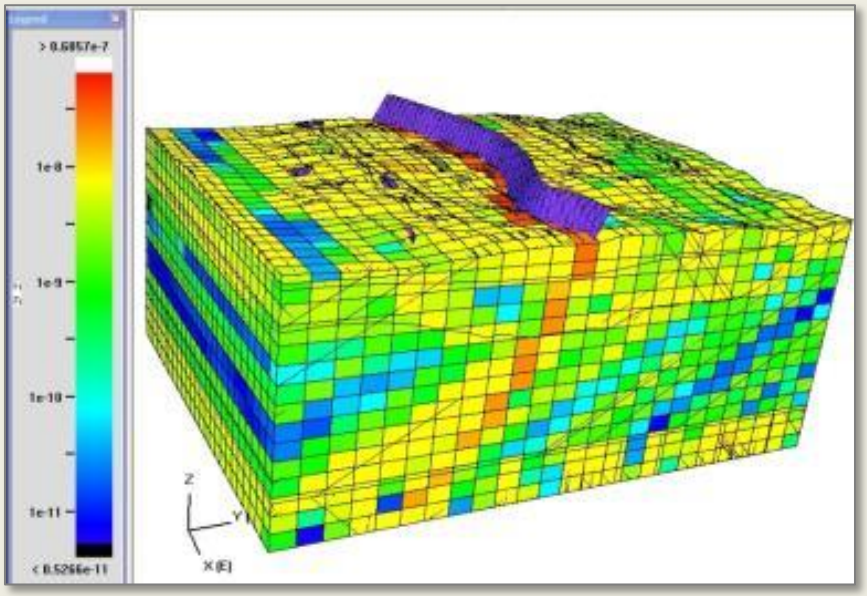


Murray, *in preparation*

Ongoing Research Objectives/Goals



- **Model pressure diffusion** from injection wells under various fluid injection scenarios, geologic conditions, and constraints
- **Describe 4D distribution of injected fluids** relative to faults, basement and high water production areas



GSA Abstracts
Carrell and Murray, 2014